

CHAPTER 2

Role & Potential of Water Recycling

California's current population of 35 million is expected to grow by roughly 17 million by 2030, a 50 percent increase. To meet the water demands associated with this growth, it will be necessary to develop a balanced portfolio of water resources, not only the traditional storage projects, but also an array of other types of facilities and management techniques, such as water transfers, water conservation, desalination, and, most certainly, water recycling. Based on the potential for additional recycled water use developed later in this chapter, recycled water could free up enough fresh water to meet the household water demands of 30 to 50 percent of the additional 17 million Californians. To achieve this potential, an investment of \$11 billion would be needed.

RECYCLED WATER USE IN CALIFORNIA

Water recycling has been taking place in California as early as 1890 for agriculture, although it is likely that the wastewater was untreated at that time. By 1910 at least 35 communities were using wastewater for farm irrigation, 11 without wastewater treatment and 24 after septic tank treatment. Landscape irrigation in Golden Gate Park in San Francisco began with raw sewage, but due to complaints, minimal treatment was added in 1912. Since then wastewater treatment standards have been greatly improved to protect public health.

By 1952 there were 107 communities using recycled water for agricultural and landscape irrigation. The first comprehensive statewide estimate of water reuse of municipal wastewater was made in 1970, when 175 thousand acre-feet of recycled water were used. In 2000, this amount had increased to 402 thousand acre-feet. The recycled water was supplied by 234 wastewater treatment plants and delivered to over 4,800 sites. Currently recycled water use is estimated to be within a range of 450 to 580 thousand acre-feet per year. The trend in use is illustrated in Figure 1.



The Golden Gate of San Francisco Bay, home of several water recycling projects to meet water needs and protect the water quality of the bay.

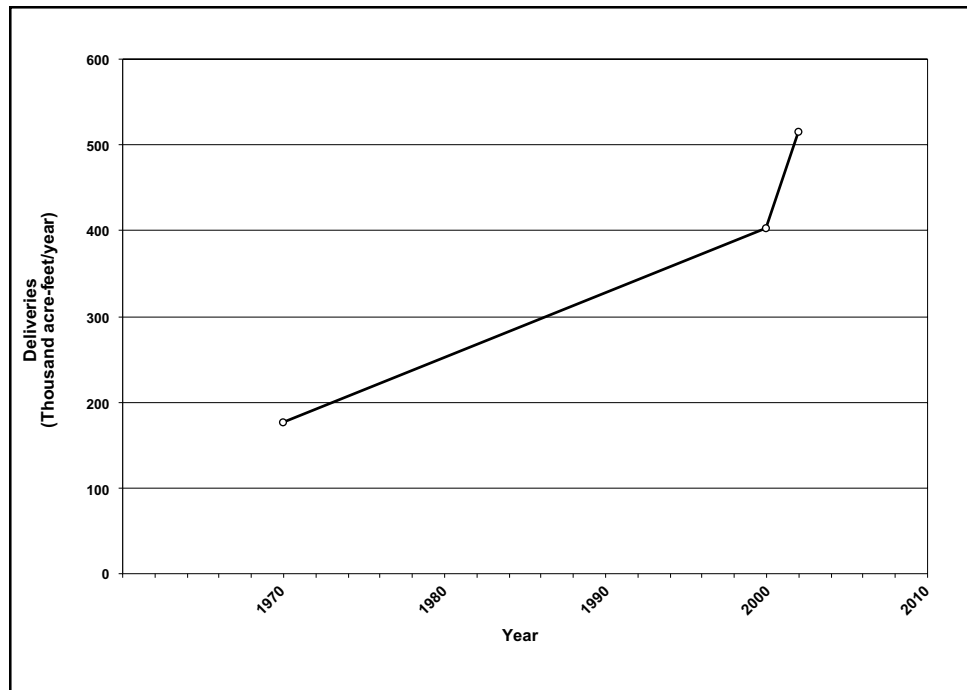


Figure 1. Recycled Water Use in California for 1970 to 2002.



Artichokes grown in Castroville with recycled water are now in markets after a 5-year study to demonstrate the safety of recycled water for food crops.

Recycled water is being used in a variety of ways, as illustrated in Figure 2. At least 20 varieties of food crops are grown with recycled water, including vegetables eaten raw, such as lettuce and celery. Eleven non-food crops, especially pasture and feed for animals, as well as nursery products, are irrigated with recycled water. Landscape irrigation is primarily for turf, including over 125 golf courses and many parks, schoolyards and freeway landscaping. Industrial and commercial uses include cooling towers in power stations, boiler feed water in oil refineries, carpet dyeing, recycled newspaper processing, and laundries. Recycled water is being used in office buildings for toilet and urinal flushing.

In many groundwater basins in California, the rate of pumping exceeds the rate of natural replenishment. Artificial recharge of groundwater is practiced in some areas by percolating either stormwater captured from streams, imported water, or recycled water into aquifers. The most notable use of recycled water for this purpose is recharge in the Montebello Forebay Groundwater Project in the vicinity of Whittier, which has occurred since 1962. In coastal areas where excessive groundwater pumping has taken place, the groundwater levels have fallen to the extent that seawater has been drawn inland, contaminating aquifers. Recycled water has been injected into the aquifers along the coast to create barriers to the seawater, thus protecting the groundwater while, in part, also replenishing the aquifer. Highly treated recycled water has been injected into a seawater barrier in Orange County since 1976 and a newer project operates along the coast in Los Angeles County.

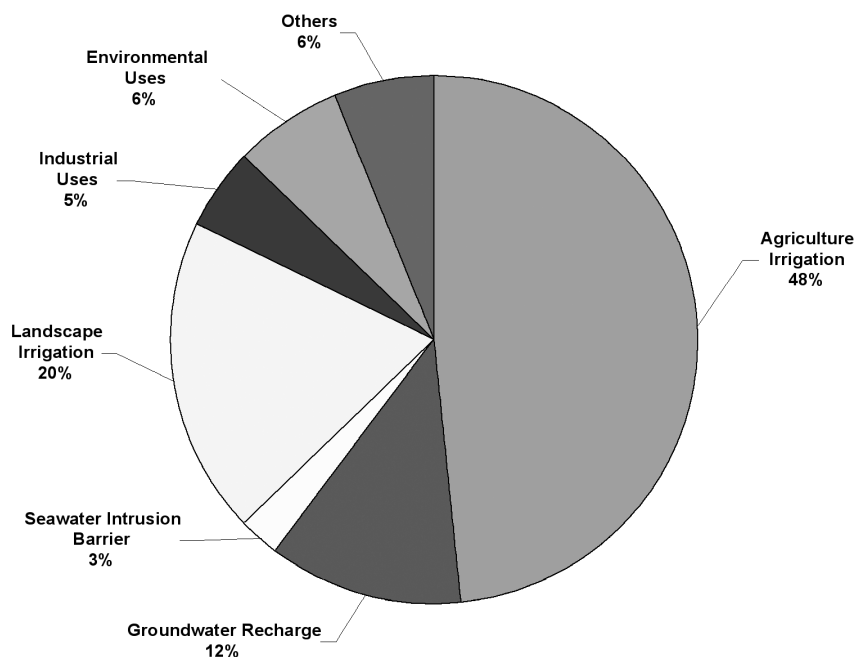


Figure 2. Types of Recycled Water Use in California (SWRCB, 2000).

WATER RECYCLING FUNDAMENTALS

Projects are initiated to serve particular objectives. Use of recycled water is motivated with a particular objective in mind and is often evaluated as one of several alternatives before determining that recycled water use is the most cost-effective means of meeting one or more objectives. There are several objectives that have led to the use of recycled water in California:

1. An incidental secondary benefit to the disposal of wastewater, primarily crop production by irrigation with effluent,
2. A water supply to displace the need for other sources of water,
3. A cost-effective means of environmentally sound treatment and disposal of wastewater,
4. A water supply for environmental enhancement.

Historically, agricultural use of recycled water predominated in California and occurred mostly in the Central Valley, where farm land was located adjacent to wastewater treatment facilities. The farm land offered a convenient place for disposal of effluent, and sometimes the sale of recycled water to nearby farmers offered a source of income to reduce costs to sewer users even when facilities were available for discharge to surface waters. As treatment standards were raised to protect the environment, land application was looked at more seriously as a cost-effective means of treatment and disposal of wastewater as opposed to discharge into streams. However, in recent decades, the emphasis in promoting water reuse has been more on the water supply benefits to meet demands in water-short areas. Water recycling is evaluated in comparison with other means of enhancing water supplies. Most projects now occur in urban areas, and uses have shifted more toward urban uses, such as landscape irriga-



Recycled water is used on vineyards in Fresno, San Diego, and Sonoma Counties.



Surface water reservoirs are a major source of water in California, but during droughts, as shown here at Lake Oroville, recycled water can be a more reliable supply.

tion and industrial use. Environmental enhancement, such as wetlands restoration, can be another, but certainly less prevalent, motivation.

Aside from meeting one or more of the major project objectives described above, there can be potential secondary benefits:

1. Provide additional reliable local sources of water, nutrients, and organic matter for agricultural soil conditioning and reduction in fertilizer use,
2. Reduce the discharge of pollutants to water bodies, beyond levels prescribed by regulations, and allow more natural treatment by land application,
3. Provide a more secure water supply during drought periods,
4. Provide economic benefits resulting from a more secure water supply.

The degree and type of wastewater treatment that is provided to make recycled water suitable for use depends on the types of use, the potential exposure of humans to recycled water and the public health implications, and the water quality required beyond health considerations. The basic levels of treatment include primary, secondary, and tertiary. Not all wastewater receives all three levels of treatment. Secondary treatment is commonly the minimum level of treatment for discharge to surface waters and for many uses of recycled water. Tertiary treatment is sometimes required for discharge to surface waters to protect fisheries or protect some uses of the waters. Tertiary treatment is often required for recycled water where there is a high degree of human contact. Disinfection is usually required for either discharge or recycled water use to kill viruses and bacteria that can cause illness.

The Department of Health Services specifies the levels of treatment for recycled water and publishes the standards in Title 22 of the California Code of Regulations. Examples of types of use and the prescribed levels of treatment are shown in Table 1. Beyond the treatment required for health protection, certain uses have specific water quality needs. High sodium or boron in water can be harmful to crops. Water hardness can cause scaling in industrial boilers. Nitrogen and phosphorus can stimulate algal growth in ponds or cooling towers. Sometimes specialized forms of tertiary treatment are needed to remove specific chemicals that would make recycled water unusable.

Most recycled water projects are designed to provide one level of water quality to all customers connected to the recycled water distribution system. If only a few potential customers need a special quality of water, it may not be economical to treat all of the recycled water to meet these special quality requirements. In recent years a more innovative approach is being practiced. Some customers with special quality needs may be served by their own pipeline from the wastewater treatment plant, and the recycled water producer provides two or more qualities of recycled water. If a single customer has special needs, the standard quality of recycled water is delivered to the customer's site and a customized treatment facility at the site provides the added treatment to bring the quality up to the standards of the customer. West Basin Municipal Water District in Southern

Table 1. Examples of Minimum Treatment Levels to Protect Public Health.

Types of Use	Treatment Level		
	Disinfected Tertiary	Disinfected Secondary	Undisinfected Secondary
Urban Uses and Landscape Irrigation			
Fire protection	√		
Toilet & Urinal Flushing	√		
Irrigation of Parks, Schoolyards, Residential Landscaping	√		
Irrigation of Cemeteries, Highway Landscaping		√	
Irrigation of Nurseries		√	
Landscape Impoundment	√	√*	
Agricultural Irrigation			
Pasture for milch animals		√	
Fodder and Fiber Crops			√
Orchards (no contact between fruit and recycled water)			√
Vineyards (no contact between fruit and recycled water)	√		√
Non-Food Bearing Trees			√
Food Crops Eaten After Processing		√	
Food Crops Eaten Raw	√		
Commercial/Industrial			
Cooling & Air Conditioning - w/cooling towers	√	√*	
Structural Fire Fighting	√		
Commercial Car Washes	√		
Commercial Laundries	√		
Artificial Snow Making	√		
Soil Compaction, Concrete Mixing		√	
Environmental and other Uses			
Recreational Ponds with Body Contact (Swimming)	√		
Wildlife Habitat/Wetland		√	
Aquaculture	√	√*	
Groundwater Recharge			
Seawater intrusion Barrier	√*		
Replenishment of potable aquifers	√*		

* Restrictions may apply

Primary Wastewater Treatment -The removal of particulate materials from domestic wastewater, usually done by allowing the solid materials to settle as a result of gravity; typically, the first major stage of treatment encountered by domestic wastewater as it enters a treatment facility. The wastewater is allowed to stand in large tanks, termed Clarifiers or Primary Settling Tanks. Primary treatment plants generally remove 25 to 35 percent of the Biological Oxygen Demand (BOD) and 45 to 65 percent of the total suspended matter. The water from which solids have been removed is then subjected to Secondary Wastewater Treatment and possibly Tertiary Wastewater Treatment.

Secondary Wastewater Treatment - Treatment (following Primary Wastewater Treatment) involving the biological process of reducing suspended, colloidal, and dissolved organic matter in effluent from primary treatment systems and which generally removes 80 to 95 percent of the Biochemical Oxygen Demand (BOD) and suspended matter. Secondary wastewater treatment may be accomplished by biological or chemical-physical methods. Activated sludge and trickling filters are two of the most common means of secondary treatment. It is accomplished by bringing together waste, bacteria, and oxygen in trickling filters or in the activated sludge process. Disinfection is usually the final stage of secondary treatment.

Tertiary Wastewater Treatment - Biological, physical, and chemical treatment processes that follow Secondary Wastewater Treatment. The most common Tertiary Wastewater Treatment process consists of flocculation basins, clarifiers, filters, and disinfection processes. The term Tertiary (Wastewater) Treatment is also used to include Advanced Treatment beyond filters.



Reverse osmosis is an advanced treatment technology that is used in certain situations where a high degree of pathogens or chemicals must be removed, especially in indirect potable reuse and industrial applications.

California has been a leader in this concept, serving several oil refineries and a seawater barrier with five qualities of water in addition to disinfected tertiary recycled water suitable for landscape irrigation. Customized treatment either at the central wastewater treatment plant or at customer sites is one possibility to add flexibility to add more customers at an acceptable cost.

Treated wastewater is reused in many areas of the State even when no projects have been constructed with this intent. For example, about 90 percent of municipal wastewater discharged in the San Joaquin Valley is reused. A discharge into a river becomes part of the river flow that may be diverted downstream for farms or other cities. This indirect reuse, that is, reuse after treated wastewater has passed through a natural body of water, is illustrated in Figure 3. A groundwater aquifer can also be the natural body for indirect reuse. Recycled water can be injected in wells or percolated from ponds and become a part of the groundwater supply that is later pumped out for use. Water that is retained in streams and wetlands maintains aquatic environments and scenic values. This “environmental water” is another unplanned benefit of indirect reuse of treated wastewater that is discharged into water bodies.

Most indirect reuse is unplanned, that is, there was no prearranged agreement or intention that the producer of the treated wastewater would maintain control of the effluent after discharge so that it would be reused downstream. The downstream reuse is an incidental result of effluent disposal by discharge and withdrawal downstream of river water. When such indirect reuse could occur, the wastewater discharge is regulated to protect the public health for the downstream beneficial use. Planned reuse typically involves direct reuse by delivering recycled water directly through pipes to the users of the water. Examples of direct reuse are also illustrated in Figure 3.

These concepts of direct and indirect reuse and planned and unplanned reuse are important in understanding the discussion of public health issues and public acceptance concerns regarding water recycling. They are also important in interpreting data on water reuse, which are not consistent in indicating whether they include only planned or only direct reuse.

Furthermore, unplanned indirect reuse already makes a vital contribution to the State’s water supply. In terms of making the greatest impact on augmenting the State’s water supply, emphasis should be placed on reusing recycled water that has no opportunity to be reused downstream, for example, discharges directly to the ocean. This understanding may affect the priority of the State’s efforts in encouraging new water recycling projects. In terms of statewide water resources planning, DWR recognizes this distinction by classifying water recycling projects in coastal and some other areas as “new water supplies” because they offset the need for other new supplies rather than offsetting downstream reuse that already may occur.

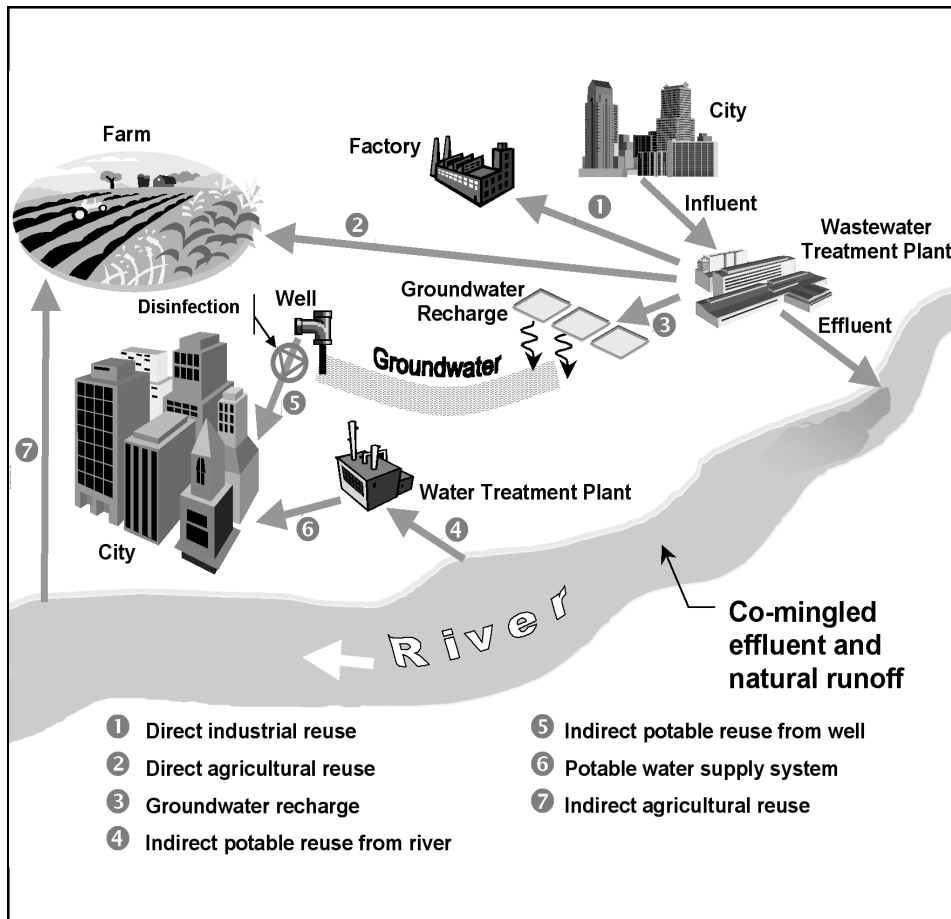


Figure 3. Direct and Indirect Recycled Water Use.

Research surveys conducted to evaluate public acceptance of recycled water have confirmed the intuitive expectation-the more direct and frequent the human contact with the recycled water, the more concern of the public, mainly related to public safety perceptions. While direct human ingestion has been proposed and researched, recycled water even with highly sophisticated treatment technologies has never been publicly accepted for direct potable use in the United States. With few exceptions nonpotable uses, including some uses with high potential for human contact, such as golf courses or schoolyards, have potential for infection or other disease to indiscernible background levels.

While direct potable reuse is not practiced, forms of indirect potable reuse have taken place in California and have been proposed. The Task Force did find a widely divergent acceptance of these indirect potable reuse concepts. Groundwater recharge by replenish-

ing groundwater aquifers with recycled water has been practiced in California since 1962 in the form of percolation from ponds through soil before reaching the groundwater and since the 1970s in the form of direct injection of advanced treated recycled water into aquifers. Because the aquifers serve as a potable water supply through wells, recharge is a form of indirect potable reuse. Various forms of tertiary wastewater treatment are provided before the recycled water is allowed to reach the aquifer. These levels of treatment are higher than would generally be required for discharges to a typical stream or the ocean. There are also natural mechanisms in the soil that provide treatment of any water that percolates down. As with all uses of recycled water, a strong governmental structure regulates the types of treatment necessary to protect public health, and generally the public has accepted the judgment of the public health authorities. However, in some communities public concern has halted the implementation of indirect potable reuse projects. The Task Force focused considerable attention to public acceptance and health issues and made recommendations to address these.

WATER RECYCLING POTENTIAL

Estimating the future potential of recycled water use is an uncertain task. Water planners will be continually evaluating a variety of alternative water sources to determine the most cost-effective and feasible options at the time. While there are increasing public health concerns not only with respect to recycled water but also with all of our sources of water, technology is becoming more effective to cope with some chemicals of concern. Technology is evolving that will make recycled water treatment, as well as alternative sources, such as desalination, more economical. As with conventional water sources, most of the cheapest opportunities to exploit recycled water have already been undertaken. It is difficult to predict exactly how recycled water will compare with alternative supply options in the long term.

Nevertheless, some studies have been conducted to estimate future potential. The most comprehensive were two regional studies covering the metropolitan areas of the Southern California coastal region and the San Francisco Bay Area. In addition, surveys have been conducted to poll agencies regarding the potential projects within their service areas. Another point of reference is the total amount of municipal wastewater that is produced or projected to occur. The amount of treated municipal wastewater produced currently in California is estimated to be about 5 million acre-feet per year. With recycled water use currently at a level of approximately 500 thousand acre-feet per year, about 10 percent of available treated effluent was reused in planned water recycling projects. California's

Recycled water, river water, and imported water feed the Rio Hondo Spreading Grounds to replenish groundwater in Los Angeles County. This indirect potable reuse has been practiced by the County Sanitation Districts of Los Angeles County since 1962.



current population of 35 million is expected to increase by 3.5 million by 2007 to 38.5 million. By 2030, the population is projected to reach 52 million, a 17 million (50 percent) increase over current population. By 2030, the amount of wastewater available for water recycling projects is estimated to increase to about 6.5 million acre-feet per year.

With these studies and projections of available wastewater as a foundation and the caveats of uncertainty, projections for recycled water use are presented in Table 2 and shown in Figure 4 in the form of ranges. In 2030, the midrange amount of projected increase in recycled water use is about 1.5 million acre-feet per year, which would be about 23 percent of the available municipal wastewater. Because of the special public health concerns that have been raised regarding indirect potable reuse, nonpotable and planned indirect potable uses have been separated in the table. Planned indirect potable uses include ground-water recharge, a portion of seawater intrusion barriers and surface reservoir augmentation for potable supply.

As was discussed earlier, many inland discharges of treated wastewater are indirectly used downstream. Thus, not all of the projected additional recycled water use is considered new water that augments the State's water supply. However, with most of the urban demand occurring in coastal areas where discharges pass through to the ocean or saline bays, it is estimated that 1.2 million acre-feet of new water will be yielded with recycled water use by 2030. When compared to the household use of the additional 17 million Californians, this new water could substitute for enough fresh water to meet the household water demands of 30 to 50 percent of the household water demand.

As with many water supply options facing California to maintain adequate future water supplies, considerable capital investment will be required for water recycling facilities. As with surface water storage, conjunctive use and ocean desalination projects, for example, funds for design and construction of recycled water projects must be raised at the outset of a project even though revenue to pay the debt will become available over many years of project operation.



Serrano's championship golf course is irrigated with recycled water in El Dorado Hills, California.

Table 2. Estimated Existing and Projected Potential Use of Recycled Water in California (taf/year).

Year	2002	2007	2010	2030
<i>Planned non-potable use</i>	400-510	520-740	770-1,000	1,520-1,850
<i>Planned indirect potable use</i>	50-70	80-120	120-170	330-400
Total	450-580	600-860	890-1,170	1,850-2,250
Increase beyond 2002		150-280	440-590	1,400-1,670

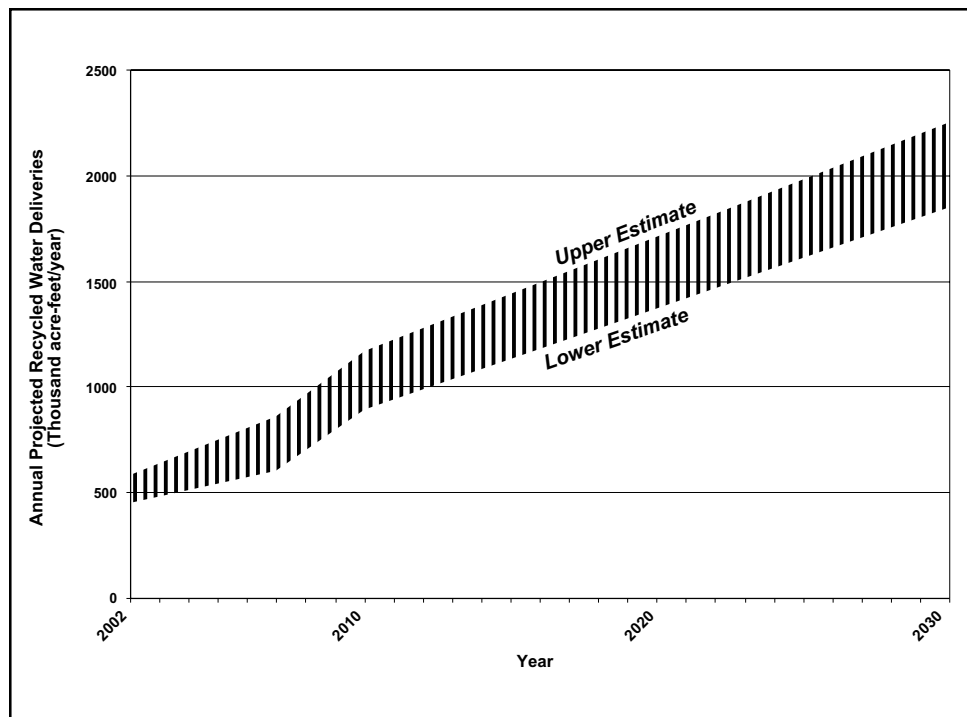


Figure 4. Projection of Recycled Water Deliveries in California through 2030.

A variety of factors can affect costs of recycled water projects, including types of use, the degree of wastewater treatment required, and the distance to deliver the recycled water. The cost to build the capacity to treat and deliver one acre-foot of recycled water annually can vary significantly. When capital costs and other factors are annualized over the life of a project, individual projects can vary from practically no extra cost to treat and deliver recycled water to over \$2,000 per acre-foot of delivered water, including capital and operational costs. It should be noted that average unit costs have been estimated to be about \$600 per acre-foot. These costs are generally comparable to other water supply options, for example, new dams and reservoirs or desalination.

Fortunately, most projects will cost well below the upper limit. Utilizing the studies referred to above, an average cost to build the capacity to yield one acre-foot per year was assumed to be \$6,500 for nonpotable reuse projects and \$6,800 for indirect potable reuse projects. The increased cost for indirect potable reuse may be due to higher levels of treatment and reliability features. Applying these unit costs to the projections in Table 1, the ranges of aggregate capital costs were estimated, as shown in Table 2.

To add 1.40 to 1.67 million acre-feet per year of recycled water by 2030, an estimated capital investment of between \$9 billion to \$11 billion will be required between now and 2030, as shown in Table 3. The cumulative investment over time is shown in Figure 5. A State bond issue, Proposition 50, was passed by voters in 2002, which included funds for water recycling projects. These funds are anticipated to take until 2005 to allocate. The average additional funds that will be needed after 2005 until 2030 are between \$360 to 430 million per year. (Note that all costs are expressed in year 2000 dollars.)

It is important to note that water recycling projects can meet water quality needs by reducing wastewater flows into the environment, increasing water that can be available to endangered species habitat, conserving energy, or achieving other needs or goals. Thus, the investment in water recycling may yield benefits beyond just meeting water supply needs.

Table 3. Total Capital Cost Estimates to Augment Recycled Water Supplies, Million dollars.						
<i>Years</i>	<i>2003-2007</i>		<i>2008-2010</i>		<i>2011-2030</i>	
<i>Range</i>	Low	High	Low	High	Low	High
<i>Non-potable use</i>	780	1,495	1,625	1,690	4,875	5,525
<i>Indirect planned potable use</i>	205	344	273	341	1,433	1,570
<i>Cumulative cost beyond 2002</i>	985	1,839	2,883	3,870	9,191	10,965
Note: Calculations based on USBR, Southern California Comprehensive Water Reclamation and Reuse Study, September 2000 draft. (Dollars expressed in year 2000 values)						

Water recycling projects are generally constructed and operated by local agencies. Operation and maintenance costs are incurred after the projects are constructed. These costs also vary widely. One sampling of proposed projects had estimated operation and maintenance costs in the range of \$70 to 490 per acre-foot, with an average of \$300 per acre-foot.

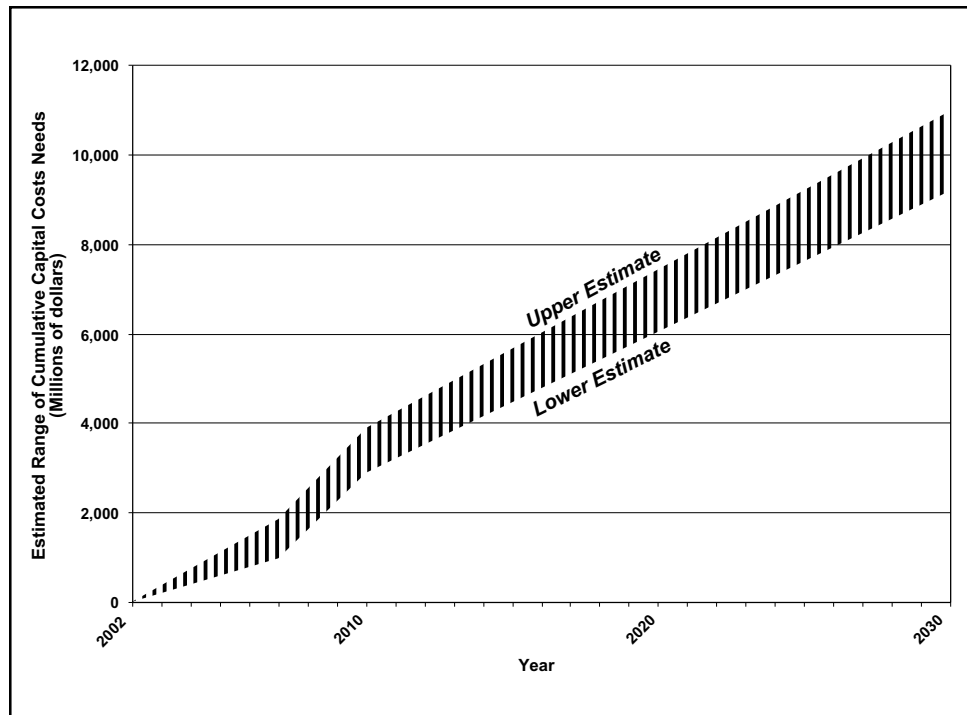


Figure 5. Cumulative Capital Investment in Water Recycling through 2030 in California.



The 12.8 mgd Recycled Water Facility of Delta Diablo Sanitation District treats recycled water for landscape irrigation and for cooling towers at electrical power stations in Pittsburg, CA.

The capital and operation and maintenance costs are recovered mainly through revenues from discharges into sewers, users of recycled water, and potable water customers who share the benefits of the added local supply of water. Freshwater projects are generally self-sustaining, but there is precedent for State or federal subsidy of water projects when particular projects have financial difficulty and there are social, economic, or environmental goals transcending a local project. Because water recycling projects are often more expensive than other local water supplies, the State and federal government have been providing subsidies for capital costs. In addition, some regional water agencies have provided annual subsidies to local agencies based on recycled water deliveries. The State funding has been in the form of low interest loans or partial grants for planning, design, and construction of projects. The sources of these funds have been bond issues, the last of which was Proposition 50 in 2002. The federal funds have been appropriations for partial grants to local agencies for design and construction. The Task Force has recommendations in Chapter 4 regarding additional funding.